how it got from tree to tree; and in the resulting discussion the fact was brought out that it had exceptionally tenacious slime. There appears to be no doubt that it is carried by birds, to which it may become attached at night while they are asleep. The Island of Porto Santo possesses a large number of endemic snails, and also a certain number of species, such as *Euparypha pisana* and *Cochlicella acuta* (the latter, new to the island, I found abundant locally north of the Villa Baleira), which have been introduced by man. But there is one species, *Balea perversa,* which was found by Wollaston only on the isolated summit of the highest mountain in the island, the Pico do Facho. This is far from human habitation, and it is nearly certain that the snail was not brought there by man. It is equally improbable that it is a member of the ancient fauna, remaining unchanged while all the other species have diverged in various directions. The strong probability is that it was carried by birds, which could reach the Madeiras in a short time, while the snails remained dormant attached to their legs. Mr. J. Y. Johnson many years ago cited no less than seventy species of birds which had been observed as visitors or stragglers to the Madeira Islands.

The indications are, nevertheless, that few species of snails can be carried long distances in this manner. Balea is exceptional on account of its arboreal habitat and tenacious mucus. There is, however, a small species common in Porto Santo, the *Heterostoma paupercula,* Lowe, which is also found in Madeira, all three Desertas, and in the Azores. I have observed that it adheres very tightly to rocks or other objects, and is very tenacious of life. Specimens which I collected in Porto Santo last January came to life and crawled about the other day on being moved from their positions. There can be little doubt, I believe, that this little snail has been distributed by birds.

It is even probable that certain species of Coccidæ (scale-insects) are dispersed in the same manner. On the top of the Portello Pass, Madeira, I found a strange little Coccid at roots of native grasses, and expected it would prove undescribed. Mr. E. E. Green, however, recognised it as *Ortheziola Vejdovskyi,* described from Central Europe. The larvæ of this insect could very well be carried on the feathers of birds, and, escaping at almost any point on the island, would be likely to find the necessary grass.

T. D. A. Cockerell.

University of Colorado, Boulder, Colorado,
November 22.

The Distribution of Brightness in the Penumbra during an Eclipse of the Moon.

On the day after the eclipse of October 16, Mr. C. E. P. Brooks mentioned to me that the edge of the umbra had seemed much more sharply defined when the eclipse was nearly total than at an early stage. This observation suggested to me that it might be worth while to work out the theoretical distribution of light over the lunar disc and gain some information about the relation between umbra and penumbra. The diagrams which commonly illustrate the theory of umbra and penumbra in the text-books are shaded in such a way as to suggest that there is a sharp discontinuity in the illumination, the umbra being indicated by one uniform shading, the penumbra by another.

A little consideration shows however that the transition from bright to dark must be gradual. From the point of view of a spectator on the moon and within the umbra the sun would be entirely hidden by the earth. To a spectator in the penumbra but close to the edge of the umbra the sun would be nearly obscured, but to a spectator near the outer edge of the penumbra almost the whole of the sun would be visible. In traversing the penumbra the proportion of the sun visible would increase slowly at first, then more rapidly, the rate of increase would reach a maximum with the sun about half obscured, and finally the proportion would change but slowly when the spectator neared the outer edge of the penumbra.

The illumination received by various parts of the moon is proportional to the area of the sun as seen by the imaginary spectator, and if the local differences in reflecting power could be ignored the apparent brightness of the disc as seen from the earth would follow the same rule.

In Fig. 1 the small and large circles represent sun and earth as seen from some point on the moon, SP $(=r)$ is the apparent radius of the sun, EP $(=R)$ is the apparent radius of the earth, and the angles PES, PSE are denoted by β and $\pi-\alpha$ respectively. The ratio of I, the illumination of the moon at the point in question, to I_0, the illumination where there is no eclipse, is determined by the fraction of the sun that is not hidden, so that

$$\frac{I}{I_0}=\frac{1}{2\pi}\left[\left(2\alpha-\sin 2\alpha\right)-\frac{R^2}{r^2}\left(2\beta-\sin 2\beta\right)\right].$$

The angles α and β which occur in this formula are related to x, the angular distance between the centres of sun and earth as seen from the moon, by the equations

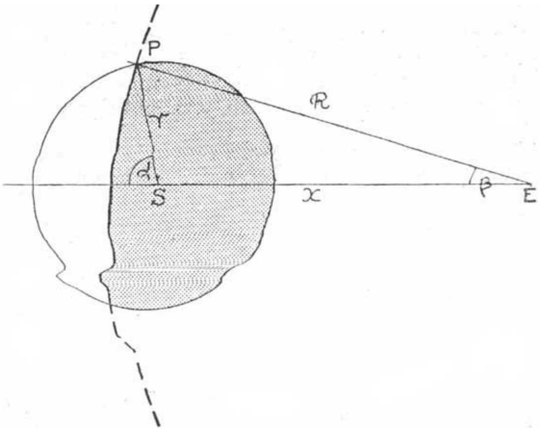

Fig. 1.

$$\frac{R}{\sin\alpha}=\frac{r}{\sin\beta}=\frac{x}{\sin(\alpha-\beta)}.$$

For R and r the mean values 16·60 milliradians and 4·64 milliradians may be adopted. On this basis I/I_0 has been plotted as a function of x in Fig. 2.

From this figure the values of x corresponding with specified values of the ratio I/I_0 have been read off; these are shown in the following table, the unit for x being the milliradian :—

I/I_0	0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
x	12·0	13·3	14·2	14·9	15·6	16·4	17·1	17·9	18·7	19·6	21·2
$(x-R+r)/2\rho$	0·00	0·14	0·24	0·33	0·41	0·49	0·57	0·66	0·74	0·85	1·03

The angle x, which was defined as the distance between the centres of sun and earth as seen from a certain point on the moon, is to a very close approximation the same as the distance of the same point of the moon from the centre of the shadow as seen from the earth.

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In Fig. 3, which shows umbra and penumbra in proportion, isopleths for each multiple of 20 per cent. of full illumination have been drawn. The ratio to the lunar diameter of the distance of each isopleth from the edge of the umbra is given in the last line of the preceding table, the lunar diameter 2ρ being taken as 9·04 milliradians. Fig. 2 exhibits the slow variation of illumination near the inner and outer edges of the penumbra which was anticipated from general considerations.

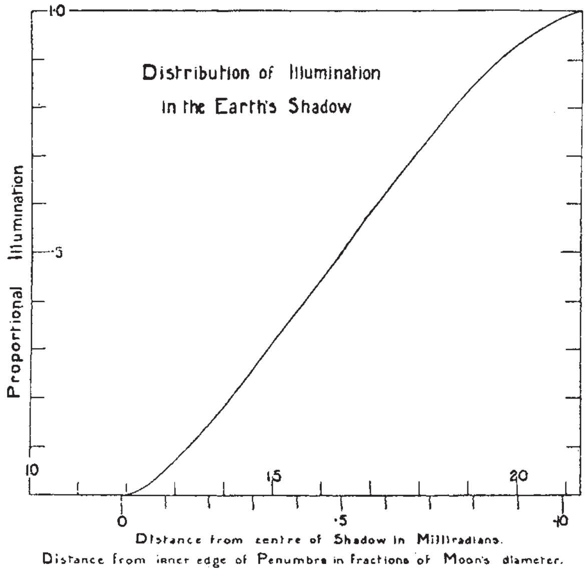

FIG. 2.

The explanation of Mr. Brooks's observations appears to be that at the beginning of a lunar eclipse the range of the brightness I is from zero nearly to I_0. The dull region, say from $I=0$ to $I=\frac{1}{3}I_0$, has a width equal to 0·24 of the lunar diameter. With the eclipse approaching totality, say when the width outside the umbra is one quarter of the diameter, the maximum illumination is only $0{\cdot}21 I_0$, and the dull strip, which in this case extends from $I=0$ to $I=\frac{1}{3}\times 0{\cdot}21 I_0$, has a width 0·08 of a diameter. The width of the dull or fuzzy region is therefore reduced in the ratio 3 : 1. If this explanation be sound the phenomenon is physiological rather than physical.

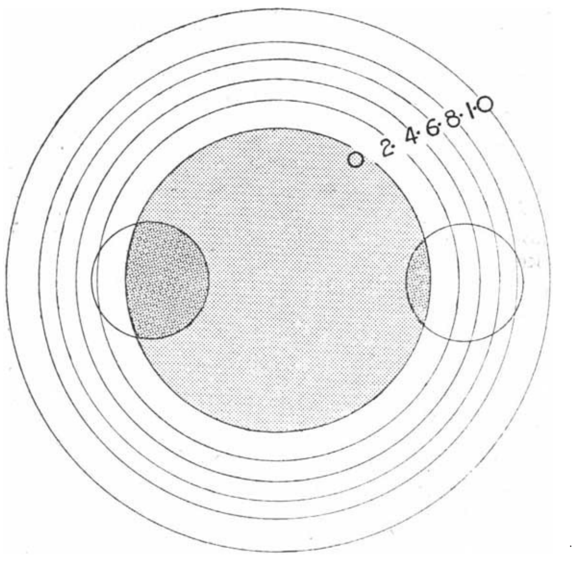

FIG. 3.—The small circles represent the moon in two positions, the shaded circle the umbra thrown by the earth, and the outermost circle the edge of the penumbra.

A lunar eclipse presents another and much more difficult photometric problem: the umbra is not perfectly black, and as is well known the slight illumination it receives is due to light refracted in passing through the earth's atmosphere. It would be of interest to compare the strength of this illumination with that in the penumbra, and hence determine the fraction of sunlight which passes through our atmosphere without loss by diffraction and absorption.

Though it is hardly relevant to the subject of eclipses, it may be mentioned that a measurement of equal delicacy and greater value would be that of the brightness of the "old moon in the arms of the new," from which measurement the mean albedo of the earth could be deduced. One may even speculate on the possibility of variation in this albedo being detected, as the earth as seen from the moon is covered mostly by land or by sea or by cloud. Such knowledge would be of considerable value in the theory of the economy of the earth's thermal energy.

The new moon is observed from England after sunset when the western hemisphere mostly covered by water is facing the moon, whereas at the end of the lunar month we see the old moon in the early morning when the eastern hemisphere with the larger proportion of land is opposite to the moon. Conditions are therefore favourable for detecting the contrast in question. F. J. W. WHIPPLE.

Meteorological Office, South Kensington,
S.W.7, November 15.

Awards to Discoverers.

IN view of the Government having enforced reductions in State funds available for research, it may be of interest to refer to the subject of awards to discoverers as means of effecting economy in, and increasing incentives to, research.

In a leading article in NATURE of March 31 last on "Inventions and Grants-in-Aid," special consideration was given to the first Report of the Royal Commission on Awards to Inventors, and also my scheme for the administration of grants for scientific discoveries and memoranda which were submitted by me to the Department of Scientific and Industrial Research. The scheme and memoranda were referred to in the article above mentioned in relation to rewards for future inventions and discoveries. In this connection I wish to direct attention to certain rulings of the Commission in respect of rewards for unpatented inventions and discoveries, particularly as the impression has been formed in certain quarters that the procedure of the Commission in respect of rewards for unpatented inventions might be made available in regard to rewards for discoveries such as those which contribute to the advancement of knowledge which it is desirable in the national interest to increase.

The discoveries for which grants may be obtained in accordance with the provisions of my scheme may be scientific or medical or surgical discoveries, and they may be described in an allocation or allocations of grants. A fund out of which grants may be allocated may be created by the State, or by means of donations and bequests, or both these sources may be made available.

I observed in my Memorandum G that "grants may be allocated to discoveries which are unremunerative,

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